APPENDIX A

VISUAL ALLOCATION MEASURES IN DRIVER WORKLOAD ASSESSMENT

APPENDIX A.   VISUAL ALLOCATION MEASURES IN DRIVER WORKLOAD ASSESSMENT

MOTIVATION

An estimated 90% of the information required for driving is acquired through the driver's sense of vision (Rockwell, 1972). This point is intuitively reasonable and has also been demonstrated in on-the-road driving and simulator studies that indicate the impact of momentary losses in visual input on drivers (Senders, Kristofferson, Levison, Dietrich, and Ward, 1967) and the effects of reduced sight distance for the road ahead (Allen and McRuer, 1977). In particular, there is but one foveal resource and it must be moved about to gather detailed visual information (Wierwille, 1993). This foveal resource is termed visual attention and its deployment by the driver is termed visual allocation. For these reasons, driver visual allocation has become an important aspect of driver human factors studies.

Early work examined the distribution of fixations across the visual field, fixation durations, fixation frequencies and percentages, and fixation sequences that are indicative of the driver's allocation of visual attention. For example, Mourant and Rockwell (1970) reported that with route familiarity, driver search and scan patterns became more compact and shifted down and to the left. Furthermore, the authors reported evidence from the eye movement records that peripheral vision is used primarily to monitor lane position and the presence of other vehicles and road signs, thus serving to direct foveal vision (and attention) as required. More recently, eye movements have been used to investigate factors that influence driver visual allocation, including vehicle factors (Kito, Haraguchi, Funatsu, Sato, and Kondo, 1989), search tasks (Louma, 1988; Hughes and Cole, 1988), visual scene complexity (Boersema, Zwaga, and Adams, 1989), and roadway parameters (Wierwille, Hulse, Fischer, and Dingus, 1988). For instance, eye movement data have revealed that drivers of large vehicles visually sample more at intersections than drivers of small vehicles (Kito, et al., 1989). Boersema et al. (1989) reported that search time and number of fixations increase systematically with the number of advertisements in search for a target word in a train station routing sign. Louma (1988) and Hughes and Cole (1988) reported that the nature of the driver's visual task affect scan patterns and direction of visual attention. Wierwille et al. (1988) found that driving-related glance times were positively correlated with increasing roadway demand characteristics (e.g., sight distance, road curvature, etc.), and in-cab navigation device glance times were negatively correlated increasing roadway demand characteristics. This suggests that drivers in the study adjusted their visual allocation appropriately to accommodate variations in driving task demand.

In addition to examination of visual allocation to elements of the road scene, work has been conducted to use eye movements as response variables to assess in-vehicle control and display workload demands. For example, Mourant, Herman, and Moussa-Hamouda (1980) reported on

the use of direct looks to in-vehicle controls of different configurations and locations as a measure of driver workload. This paper explicitly posited that:

> "The positioning of controls so as to minimize direct looks will permit the driver to spend more time monitoring the forward scene for potentially dangerous events." (p, 417).

Mourant et al. (1980) found that the frequency of driver direct looks increased with increased hand travel distance to reach a control and also that look durations increased with increasingly complex control configurations.

Rockwell (1988) reported on the use of glance frequencies and glance durations as measures of driver in-vehicle visual performance. His data indicate that glance durations tend to be consistent and independent of the mean number of glances required to complete an in-cab task (e.g., radio tuning). Average glance duration is somewhat sensitive to task demand, though truncated because most drivers are unwilling to take their eyes off the road for more than perhaps 2 s. Bhise, Forbes, and Farber (1986) also reported that in-cab task demand has some effect on average glance duration but a much larger effect on glance frequency. Wierwille (1993) developed a driver visual sampling model that describes this behavior.

Most recently, extensive research has been carried out using visual allocation measures to assess attentional demand of in-cab controls and displays (see Wierwille, 1993 for a review). For example, Dingus, Antin, Hulse, and Wierwille (1989) recorded passenger car driver mean glance duration and mean number of glances for a wide variety of in-cab instruments and an operational in-vehicle route navigation system. Mean glance durations varied from approximately 0.62 s to 1.66 s while the mean number of glances to complete an in-cab transaction varied from 1.26 to 6.91 glances (see Table A-l). Tijerina, Kantowitz, Kiger, and Rockwell (1994) reported on the visual allocation of heavy vehicle drivers fixating on mirrors and various instrument panel devices during an on-the-road pilot study. As can be seen in Table A-2 the mean or average glance durations varied from approximately 1.06 s to 2.11 s while mean number of glances varied from 1.25 to 7.81 glances. Comparing across like in-vehicle device use, it appears that the heavy vehicle driver mean glance durations tended to be longer and more glances were required than was the case with the Dingus et al. (1989) passenger car drivers. Such differences underscore the need to collect baseline visual allocation data for both passenger car and heavy vehicle applications. Wierwille (1993) presents a task classification that predicts the variation in visual demand reflected in both sets of data.

While visual allocation measures are useful for driver workload assessment, they are not perfect. In particular, visual allocation measures are limited by the following points:

- The majority of interstate highway driving requires less than 50% of the driver's visual capacity (Rockwell, 1972). The driver therefore samples a large amount of extraneous information.

Table A-l. Passenger Car Driver Mean Glance Duration and Mean Number of Glances Associated with Various In-Vehicle Tasks (Source: Dingus, Antin, Hulse, and Wiexwille, 1989).

Task	hear Single Glance Length		Number of Glances	
	Maan	Standard Deviation	Mean	Standard Deviation
Speed	0.62	0.48	1.26	0.40
Following Traffic	0.75	0.36	1.31	0.57
Time	0.83	0.38	1.26	0.46
Vent	0.62	0.40	1.83	1.03
Destination Direction	1.20	0.73	1.31	0.62
Remaining Fuel	1.04	0.50	1.52	0.71
Tone Controls	0.92	0.41	1.73	0.82
Info. Lights	0.83	0.35	2.12	1.16
Destination Distance	1.06	0.56	1.73	0.93
Fan	1.10	0.48	1.78	1.00
Balance	0.86	0.35	2.59	1.18
Sentinal	1.01	0.47	2.51	1.81
Defrost	1.14	0.61	2.51	1.49
Fuel Economy	1.14	0.58	2.48	0.94
Correct Direction	1.45	0.67	2.04	1.25
Fuel Range	1.19	1.02	2.54	0.60
Cassette Tape	0.80	0.29	2.06	1.29
Temperature	1.10	0.52	3.18	1.66
Heading	1.30	0.56	2.76	1.81
Zoom Level	1.40	0.65	2.91	1.65
Cruise Control	0.82	0.36	5.88	2.81
Power Mirror	0.86	0.34	6.64	2.56
Tune Radio	1.10	0.47	5.91	2.39
Cross Street	1.66	0.82	5.21	3.20
Roadway Distance	1.53	0.65	5.78	2.85
Roadway Name	1.63	0.80	6.52	3.15

Note: Glance length given in seconds.

Table A-2. Truck Driver Visual Allocation Data to mirror and instrument panel locations. (Source: Tijerina, Kantowitz, Kiger, and Rockwell, 1994).

Command	No, of Trials	Total No, of Glances	Average Glance Duration (Secs.)	Variance of Glance Duration (Secs. Sq.)	10th %tile Glance Duration (Secs.)	90th %tile Glance Duration (Seer.)	Mean No. of Glances	Min. No. of Glances	Ma. No. of Glances	Average Time OK Road* (Secs)
Left Mirror-Dctcct (3)	I7	24	1.38	0.39	0.67	2.23	1.41	1	3	1.95
Right Mirror-Detect (8)	17	26	1.22	0.27	0,57	1.73	1.59	1	4	1.94
Left Mirror-Discrimination (I 5)	12	16	1.52	0.4 I	0.30	2.17	1.50	1	3	2.28
Right Mirror-Discrimination (19)	14	26	1.45	0.38	0.73	2.43	1.86	1	3	2.69
Read Exact Speed (1)	21	27	1.60	0.28	1.00	2.40	1.29	I	2	2.06
Read Speed & Comperc to Posted Limit (1 1)	16	20	1.42	0.26	0.77	2.08	1.25	I	2	I.77
Read Air Pressure (2)	19	38	2.11	1.32	0.67	3.85	2.00	I	9	4.21
Read Engine **RPM (5)**	**18**	28	1.66	0.50	0.73	2.55	1.61	1	3	2.67
Read Fuel Gage (16)	18	32	1.88	0.50	0.75	2.77	1.78	I	4	3.34
Read Clock (9)	17	3 2	1.20	0.28	0.48	1.77	1.88	1	7	2.25
Read Elapsed Time (20)	12	32	1.65	0.27	0.98	2.33	2.67	1	6	4.40
Radio Volume Up/Down (4)	34	55.	1.1	0.18	0.40	1.47	1.62	I	3	1.78
Scicct Preset Station (17)	16	51	1.46	0.50	0.63	2.50	3.19.	1	7	4.65
Tune Radio to 90.5 (18)	16	125	1.77	0.4 I	0.97	2.67	7.81	3	18	13.81
Change CB Frcqucncy (G)	33	122	1.34	0.22	0.73	2.00	3.76	2	7	5.04
Turn CB Volume Up/Down (7)	24	31	1.06	0.14	0.50	I.53	1.29	1	3	1.37
AC Temp Up/Down (21)	5	12	1.65	0.51	0.80	2.57	2.40	1	4	3.97
Fan Speed Higher/Lower (22)	7	12	1.35	0.23	0.62	1.90	1.71	1	**3**	2.3 I

* Product   Glance   Number of Glances

- Foveal vision is considered important for many aspects of driving and crash avoidance like sign reading and object and event detection. On the other hand, peripheral vision may be primary in detecting relative motion, which is also an important aspect of hazard detection (Liebowitz and Owens, 1986; Shiff and Arnone, 1995).

- The driver's gaze usually, but not always, indicates where the driver's attention is focussed.

These caveats suggest that visual allocation measures may be useful but should be augmented by other measures of attentional demand and intrusion on the driving task caused by in-cab devices. It is also important to keep in mind that there are other eye movement measures that are not included in the definition of visual allocation measures. These include measures such as pupil diameter, blink rate, eyelid closure, slow eye movements (SEMs), and others. Such measures have their uses (e.g., in drowsy driver detection) but are not considered to reflect the direct acquisition of visual information for safe driving.

INSTRUMENTATION NEEDS

The measurement of eye movements can be accomplished by a variety of methods (see Young and Sheena, 1975 for a review of basic methods). These include electro-oculographic (EOG) methods, pupil-center-corneal-reflection techniques, and film or video of the driver's face and eyes. Eye movement or visual allocation techniques for use in vehicles should ideally: a) allow the driver to use normal visual scanning strategies; b) allow the driver a full range of free head and upper-body movements; c) operate under various lighting conditions (day and night) and the vibration environment of the vehicle; d) provide sufficient resolution on where the driver is looking; and e) be reducible by automatic means.   While innovative instrumentation options are currently under development (cf. Hagiwara and Zwahlen, 1995), no visual allocation system is currently available to meet all of these needs. In particular, head-mounted systems are of concern from the standpoint of driver acceptance and restricted field of view. The performance of systems that depend on infrared light sources (e.g., pupil-center-corneal reflection techniques) is degraded in bright daylight. Sensors that track head position are currently expensive to procure. There are conditions were high resolution of fixation location is required (1 degree of visual angle or less). Examples include the need to determine where a driver is looking among closely spaced instruments or among data items in a visual display or a head-up display (HUD). Currently, no instrumentation (known to the authors) is available for use in a operational environment that provides such resolution without encumbering the driver to at least some extent.

At present the simplest and most reliable means to collect visual allocation data is by means of videotape with manual data reduction. It is tedious work, but effective and so the instrumentation needs for the video method with manual data reduction are described next. The

fact that manual data reduction is most common now should in no way detract from the need to develop computer-assisted data reduction (and enhanced precision in data capture) in the future.

The collection of driver visual allocation data on-the-road requires a variety of instrumentation that can be grouped into two systems: a data capture system and a data reduction system. Key components are described below.

DATA CAPTURE SYSTEM

The following components constitute parts of the data capture system for visual allocation data gathering.

- A <u>power source</u> is needed for all equipment. This power source should be conditioned to minimize equipment malfunction and data loss or inaccuracies due to power fluctuations.

- A <u>camera</u> must be mounted so that it may be directed toward the driver's face. This view is required to record the driver's visual glances during the data collection run. The camera should be equipped with a lens so focussed as to provide a clear image of the driver's face such that minor head movements do not cause the driver's face to be lost from the recorded image. It is important to position the camera and its mount in such a location that their presence does not affect the driver's view of the driving scene.

For night data collection, there will also be a need for an <u>infrared light source</u> to illuminate the driver's face.

- A recording system is needed, such as a <u>video cassette recorder</u> (VCR). The VCR should use high-quality <u>video tape</u> for good resolution. The recording system should be set to run at the fastest recording speed, if possible, for best picture resolution.

- A <u>video monitor</u> is needed to examine the quality of the recorded image.

- A <u>calibration video</u> must be made wherein the driver is asked to systematically look in pre-specified locations. Periodically, recalibation video should be taken to aid in the data reduction.

- A <u>time-code generator</u> is needed that superimposes time information on the view of the driver's face prior to recording on the VCR. The device should provide a high-speed elapsed time clock with resolution equal to the video frame rate (e.g., l/30th of a second for one video frame assuming NTSC standard video at 30

frames per second; 1/25 of a second for one video frame assuming PAL standard video at 25 frames per second).

- It is advisable to have <u>additional cameras</u> and VCRs to capture the road scene ahead and in-cab activities. If so, it is recommended that there be an <u>additional VCR</u> and a <u>four-into-one video splitter</u>.   One VCR can record the driver' s face. The second VCR can be used to record a split screen view of, for example, the driver's face, the road scene ahead, the in-cab scene, and an additional camera view of the driving situation.   The time code generator must superimpose the same time code on both recordings. Finally, a <u>video switcher</u> is required if the experimenter wishes to periodically view each video recording on the video monitor to ensure proper camera aim following in-route seat adjustments or postural changes made by the driver.

- <u>Micronhones</u> can be readily interfaced into the video data capture system and audio recordings may be made. This option should be considered to capture driver comments or experimenter comments.

- <u>Auditory or visual event markers</u> can be recorded on the video tape to facilitate cuing during data reduction.

Figure A-l presents a schematic of one data capture system. The configuration depicted includes two cameras oriented to the road scene ahead, one camera to the driver's face (the "gaze" camera) and one in-cab camera oriented to capture hand movements off of the steering wheel (the "hands-on-wheel" camera).

DATA REDUCTION SYSTEM

The data reduction system is used to take visual allocation data from the videotape for subsequent analysis. The components of such a system, suitable for manual data reduction, are presented below. Note that advances in automatic image processing may automate much of the data reduction involved, though manual data reduction is currently the most common and reliable method used.

- A professional editing video cassette recorder or <u>editing; deck</u> is used for playback. The VCR or editing deck should not suppress the audio recording during slow motion or search-speed playback. This is because the audio is needed to detect time codes and auditory event markers, if used. An additional desirable feature is the ability to enter in a time code for automatic search and cuing. The unit should allow for frame-by-frame advance.
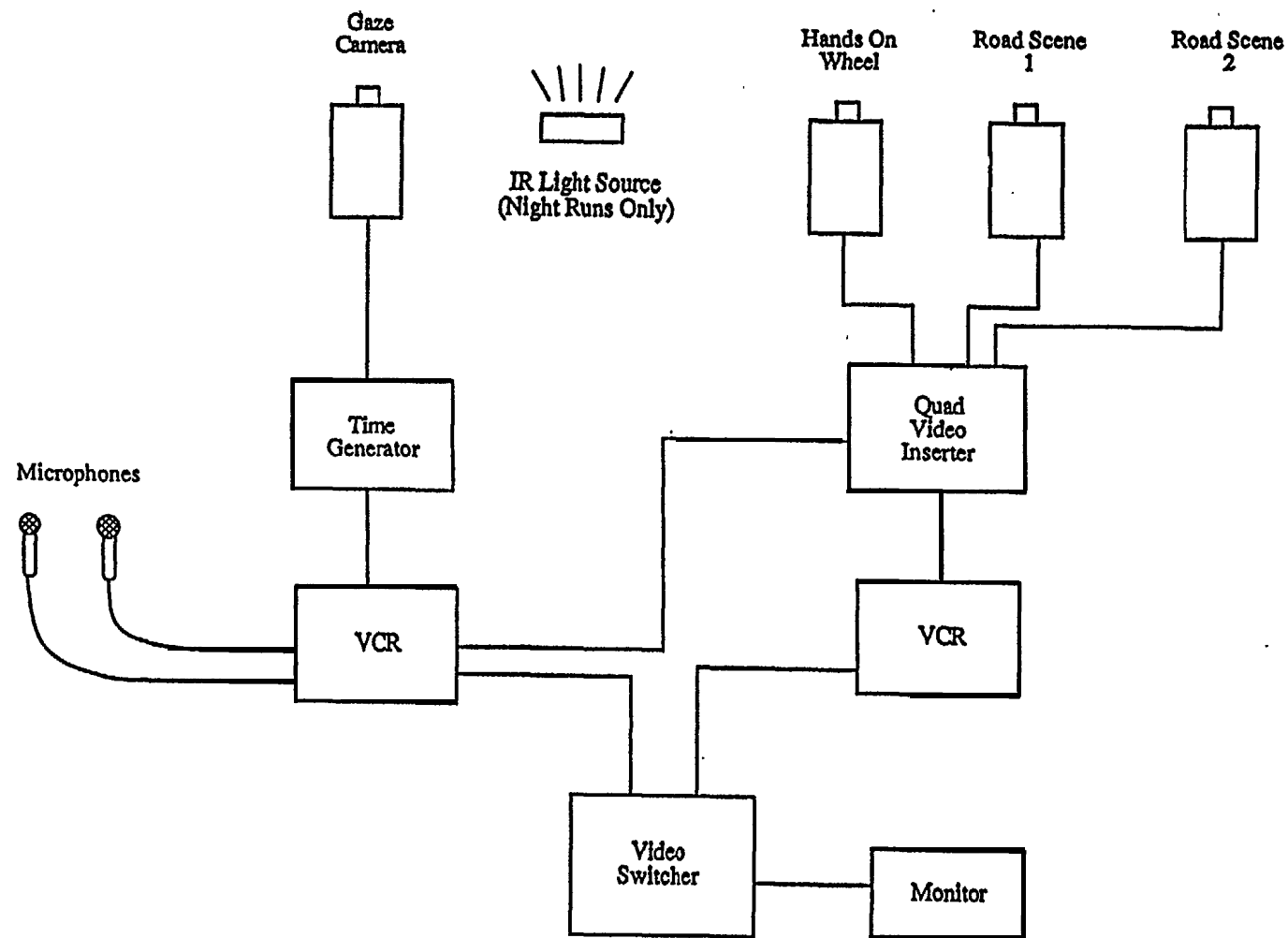
Figure A-1. Schematic of a Visual Allocation Data Capture System for Instrumented Vehicle Use.

- A <u>video nlayback monitor</u> is needed to allow the data reducer to review the video tape.

To expedite data reduction, it is advisable to develop a computer interface that can accept the start and stop times for each glance to a location as well as the location code entered by the data reducer. The additional equipment required is listed below:

- A <u>time code reader</u> is needed, interfaced to a PC, to capture the start and end time codes for each glance.

- A PC with custom software is needed to read time codes directly from the videotapes and store them in a database along with the location code selected by the data reducer.

The following terms are defined for the data reducer:

Sample
Interval: A time period that constitutes a sample of interest (e.g. an in-cab task) of the videotape for data reduction. Usually, this will be the time associated with an event.

Frame: The basic unit of observation for data reduction. The data reducer examines a video display frame by frame, to determine the driver eye fixations.

Fixation
Location: Where, in a pre-defined mapping of areas, the driver is looking in a given frame. As was mentioned earlier, a calibration video must be recorded wherein the driver is asked to look at pre-specified locations so that the data reducer may allocate fixations across locations from frame to frame reliably. Furthermore, different locations must have some minimum spatial separation to be distinguishable on the videotape.

Transition: A change in eye fixation location from one defined fixation location to another, different, fixation location.
Transition
pair: The From-To pair of fixation locations in a given transition.

Gaze Shift: A change in the driver's eye point-of-regard, in a given frame, that is between pre-defined fixation locations.

Given these background definitions, the following procedure should be followed:

1) The data reducer advances the videotape to the start of a <u>sample interval</u> of interest.

2) The data reducer examines the first <u>frame</u> of the driver's face and determines the driver's <u>fixation location,</u> then enters that location code and the starting time for that fixation.

3) The data reducer advances the video tape, frame by frame, until the driver's eyes move to another location. When this occurs, the data reducer enters the new fixation location code and the time code for that frame. The data reducer also indicates that this is the first <u>transition pair</u> from the first location (e.g., location j) to the second location (i.e., location j).

4) If one or more frames indicate <u>gaze shifts</u> (i.e., the driver's eyes are in motion and between defined fixation locations), the data reducer may select one of the following options:

   - The frame(s) may be deleted. This is suitable if the analysis does not require that all of the time in the sample interval be accounted for. For example, an analysis of mean glance durations and glance frequencies would not require all of the sample interval time to be accounted for.

   - Allocate the frames containing gaze shifts to the original fixation location until the new fixation location is reached. This convention is based on plausible assumptions that a) the driver is still processing information just picked up from the original fixation location and b) does not begin picking up and appreciating information from the new fixation location until the eyes are on the location and have re-accommodated or refocussed. This option will allow for all of the sample interval time to be accounted for, subject to a small bias introduced in the glance duration data which may overstate glance duration to some extent.

   - Collect the time required for gaze shifts explicitly for analysis of transition times, times required to shift the eyes from one location to another. This will also account for the total sample interval.

5) The previous steps are repeated frame-by-frame until the sample interval has been fully reduced.

FUNDAMENTAL DATA

Given the reduced data, it is possible to determine three fundamental measures: glance durations, glance frequencies, and transition pairs. Each of these is operationally defined below.

A-11

Glance: A series of consecutive fixations (frames) on the same location. A glance is indicated by the same fixation location across multiple consecutive video frames.

Glance Duration: The time that a driver's eyes are stationary (disregarding small movements) on a single fixation location. This is taken as the time interval from when the driver first fixates on a location until the driver's eyes shift to a different location.

Number of Glances: The total number of glances to a particular location in the sample interval, where each glance is separated by at least one glance to a different location.

Transition Pair: A change in eye fixation from location j to location k where j is not equal to k.

Transition Time: The time interval required for the eyes to move from location j to location k. This time interval is essentially linear with distance traveled during the gaze shifts. Hayes, Kurokawa, and Wierwille (1989) report that transition time also increases with age and, for their study, averaged between 100 ms (for drivers 18 to 25 years of age) and 125 ms (for drivers 49 to 72 years of age).

From these fundamental measures, the visual allocation measures of performance (MOPs) in Table A-3 can be derived. The table consists of the following elements:

- Operational Definitions of each MOP

- Workload interpretation, i.e., a prediction of how the MOP should vary with increased workload.

The analysis of the MOPs may be conducted using a variety of statistical techniques. These range from t-tests and ANOVAs on mean values to Chi-square tests for homogeneity of proportions for fixation probability data, to multivariate procedures (MANOVA, cluster analysis, regression), to exploratory graphical data analysis techniques. The references included at the end of this appendix provide examples of various analysis procedures.

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Table A-3. Visual Allocation Measures of Performance (MOPs) used for Driver Workload research. Note: All measures are taken within a sample interval and, unless otherwise noted, are defined with respect to a given fixation location j (e.g., in-cab device, roadway, mirrors, etc.), for a single driver.

Number of Glances$_j$ =	Total number of glances to location j, where each is separated by at least one glance to a different location..
Workload Interpretation:	The number of glances needed to complete a transaction reflects the complexity of the in-cab task as a whole, i.e., the number of task components (Kurokawa and Wierwille, 1990). Thus, the greater the workload demanded by a location (e.g., device, road scene), the greater the glance frequency.

Mean Glance Duration$_j$ =

$$\frac{\left(\sum_{i=1}^{n} Glance\ Durations(i) \right)}{Number\ of\ Glances_j}$$

The mean glance duration to location j is the sum of all glance durations to location j divided by the number of glances to location j in the sample interval.

Workload Interpretation: The average length of a single glance reflects the difficulty of a task component (Kurokawa and Wierwille, 1990). Subject to the constraint that most drivers will not take their eyes off the road for more than perhaps 2.0 to 2.5 s, longer glances, the greater the workload demand, the longer the mean glance duration.

Note that glance frequency and glance duration may trade off within a fixed sample interval. That is, very long glance durations (indicative of high workload demand) may be associated of with fewer rather than more glances. Thus, it is important to consider the two measures together, especially if the sample interval is fixed rather than allowed to reflect task completion time.

Table A-3. (Continued). Visual Allocation Measures of Performance (MOPs) used for Driver Workload research. Note: All measures are taken within a sample interval and, unless otherwise noted, are defined with respect to a given fixation location j (e.g., in-cab device, roadway, mirrors, etc.), for a single driver (Continued)

Total Glance Time$_j$ =

$$\sum_{i=1}^{n} Glance\ Duration_j(i)$$

i.e., total glance time to fixation location j is the sum of all glance durations to fixation location j in the sample interval.

Proportion Total Glance Time$_j$ = [Total Glance Time$_j$ / Sample Interval]

Workload Interpretation: The total glance time (or percentage of time) associated with a fixation location j (e.g., in-cab device) provides another measure of the visual demand posed by that location. The percentage measure may be used when there is a need to normalize total time measures based on the length of the sample interval. As workload demand increases, total time and percent time should increase.

Key measures that should be considered for driver workload assessment include Total Glance Time and Proportion of total Glance Time to the following key locations: on-road, on-mirrors, in-cab (i.e., on an in-vehicle device).

Table A-3. (Continued). Visual Allocation Measures of Performance (MOPs) used for Driver Workload research. Note: All measures are taken within a sample interval and, unless otherwise noted, are defined with respect to a given fixation location j (e.g., in-cab device, roadway, mirrors, etc.), for a single driver (Continued)

Mean Transition Time$_{jk}$ =

$$\sum_{i=1}^{n} \frac{gaze\ shift_{jk}(i)}{n_{jk}}$$

where

gaze shift$_{jk}$(I) is the transition time for the eyes to shift gaze from location j to location k for transition I;

n$_{jk}$ = number of transitions from location j to location k in the sample interval.

i.e., mean transition time is the sum of the gaze shift times to move the eyes from location j to location k, divided by the number of such gaze shifts in the sample interval.

Workload Interpretation: Transition times are roughly a linear function of the distance from location j to location k. During the transition gaze shift, there is relatively little new visual information available to the driver. Thus, increased mean transition times reflect reduced time available for driver information gathering.

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Table A-3. (Continued). Visual Allocation Measures of Performance (MOPs) used for Driver Workload research. Note: All measures are taken within a sample interval and, unless otherwise noted, are defined with respect to a given fixation location j (e.g., in-cab device, roadway, mirrors, etc.), for a single driver (Continued)

Fixation Probability, p_j:

$$p_j = \frac{number\ of\ frames\ with\ gaze\ on\ location\ j}{total\ number\ of\ frames\ in\ sample\ interval}$$

i.e., Fixation probability is the probability that location j was fixated on during a sample interval.

Workload Interpretation: The fixation probability on a given location reflects the relative attentional demand associated with that location. Across a mutually exclusive and exhaustive set of locations, fixation probabilities capture where the eyes were fixated throughout a sample interval. Given such a distribution, workload assessment might statistically compare two such distributions (under two different task types, for example). For example, if device use induced a relative decrease in the fixation probabilities associated with the driving scene (e.g., road scene, rear-view mirrors), this would be considered safety relevant and indicative of the workload demand associated with the device.

Table A-3. (Continued). Visual Allocation Measures of Performance (MOPs) used for Driver Workload research. Note: All measures are taken within a sample interval and, unless otherwise noted, are defined with respect to a given fixation location j (e.g., in-cab device, roadway, mirrors, etc.), for a single driver (Continued)

Link Value Probability, p_{Ljk} :   This is a measure of the strength of association between location j and location k. According to Wierwille (1981; see also Antin, Dingus, Hulse, and Wierwille, 1990) ,the link value probability between location j and location k is:

$$ p_{Ljk} = \frac{\dfrac{n_{jk}}{N} + \dfrac{n_{kj}}{N}}{N - \displaystyle\sum_{j=1}^{Q} \dfrac{n_{jj}}{N}} $$

where

n_{jk} =   the number of transitions from location j to location k, j not equal to k.

n_{kj} =   the number of transitions from location k to location j, k not equal to j.

n_{jj} =   the number of transitions from location j to location j (i.e., successive frames where the driver's fixation location remains the same).

N =   the total number of transitions (across all locations, not just j and k) in the sample interval.

Q =   the number of unique fixation locations.

It should be noted that p_{Ljk} is only defined for j < k. Thus, the number of link probabilities for a situation in which there are Q locations is given by $[Q(Q-1)]/2$.

Workload Interpretation: The link value probabilities represent the relative number of transitions between one location and another and, thus, the strength of relationship between one location and another. The greater the link value probability, the stronger is the need to time-share attention between the two locations. In workload assessment, the link value probabilities may be analyzed to assess how visual attention has been affected by an in-cab device use or driving conditions.